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REDUCTION IN AUDIOGRAM SHIFTS IN SONAR WATCHSTANDERS WHEN EXPOSED TO SURFACE SHIP ECHO-RANGING

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SUMMARY PAGE

THE PROBLEM

To determine the deleterious effects, if any, on the hearing of sonar watchstanders using unmodified earphones during two typical 10-day cruises of USS GATO (SSN 615) when exposed to moderately heavy surface ship echo-ranging; and to determine whether peak-limiting circuitry installed by NUSC/NLON for two special earphones reduced these deleterious effects to innocuity.

FINDINGS

On both cruises, about 50% of the men who used unmodified earphones exhibited temporary hearing losses greater than a nationally-proposed damage risk criterion. None of 6 men on the second cruise who used the modified earphones had any noticeable problem. The effect on sonar efficiency of this particular manner and/or level of peak-limiting has not been studied.

APPLICATION

For the use of sonar systems engineers and medical personnel responsible for hearing conservation programs.

ADMINISTRATIVE INFORMATION

This investigation was carried out as a part of Bureau of Medicine and Surgery Work Unit MF12.524.004-9010D - Optimization of Auditory Performance in Submarines. The present report is No. 12 on this work unit. The manuscript was approved for publication on 21 May 1971 and designated as Memorandum Report No. 71-4.

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ABSTRACT

Audiograms on sonar technicians collected on the submarine USS GATO, SSN 615, during exposure to echo-ranging noise, during the period 19 - 31 January, showed that the sound pressure levels (SPLs) in the sonar headsets might be hazardous to hearing. Therefore, two of three headsets used on that ship were modified by personnel at the Naval Underwater Systems Center, New London Laboratory (NUSC/NLON) so as to limit the peak SPLs delivered to the user's ear, and audiometry studies were planned for a subsequent cruise.

On a cruise during the period 21-31 March 1971, during which light to moderately heavy echo-ranging was encountered, six men using an unmodified headset were exposed to SPLs of 118 dB, and in half of the twelve ears involved a temporary hearing loss was found which exceeded a widely-disseminated damage-risk criterion. The other six men used modified headsets. They showed no average loss whatever, and only one ear slightly exceeded the criterion.

Further studies are in progress to ascertain whether the modification introduced for this occasion was an optimal compromise between protecting the ears versus obtaining all possible information from the sea.

REDUCTION OF AUDIOGRAM SHIFTS IN SONAR WATCHSTANDERS WHEN EXPOSED TO SURFACE SHIP ECHO-RANGING

INTRODUCTION

Concern has recently been felt that submarine sonar technicians, in the proximity of surface ships actively echo-ranging, may be exposed to sound pressure levels (SPLs) potentially damaging to hearing. The Navy's Hearing Conservation Program [1] does not cover the case of such impulsive sounds, and, in fact, no national standards exist to specify safe SPLs. However, the Naval Submarine Medical Research Laboratory (NSMRL) has tentatively set a damage risk criterion (DRC) of 90 dB on the basis of its research on such sonar signals, considering pulse duration, SPL, sound-on-time, and duration of the watch [2, 3, 4]. For less frequent exposure, such as encountered in many at-sea operations, the DRC may be raised to 95 dB [5].

By COMSUBLANT directive [6], the Naval Underwater Systems Center, New London Laboratory (NUSC/NLON) and NSMRL were directed to investigate this problem area, and make recommendations. NSMRL addressed the specific question of effects on human hearing and performance of listening on BQS-6 and BQS-7 earphones to surface ship echo-ranging [7]. It was recommended that peak-limiting circuits in the sonar earphone line be set to clip at 95 dB SPL and be fail-safe, but that if the clipper must be set at 100 dB SPL, an individual sonar watch should not exceed two hours.

Some preliminary data were collected by HM1 CLASSEN on USS GATO (SSN-615) during a cruise 19-31 January 1971, using an audiometer loaned by NSMRL. Eleven sonar technicians were examined before and after specific sonar watches during which surface ship echo-ranging was encountered. These data were turned over to NSMRL. Unfortunately, time had not been available to take more than a relatively few audiograms and these had to be taken in rather gross 10 dB steps. Moreover, an octave-band analyzer had not been available to determine noise levels existing in the audiometric workspace, nor had a flat-plate coupler been available to measure the SPLs generated in the sonar headsets during echo-ranging. The results were not published, because of the uncertainties of interpretation, but on face value, it would appear that about half of the 22 ears involved had temporary hearing losses of over 20 dB at 4 and/or 6 kHz. It was concluded that a problem might indeed exist and that a careful study should be initiated.

By letter from the Officer-in-Charge, NSMRL, [8] The Commanding Officer, USS GATO (SSN-615) was invited to have SPLs measured in the sonar headsets during a variety of actual operating conditions on a forthcoming cruise, together with audiograms and measures of noise in the audiometric workspace, according to a brief protocol included as Enclosure (1) to that letter.

In the interim, HM1 CLASSEN reported to NSMRL for more complete training in audiometry, especially in the use of an AMBCO portable unit, Model 601-D in 5 dB steps, and fitted with "Auraldome" circumaural cushions. He was also given practice in the use of the General Radio 1558A octave band analyzer and the NSMRL flat-plate coupler used to mate headset to a microphone. All these items, together with reporting sheets were loaned to USS GATO by NSMRL. During 25-30 March 1971, the protocol was successfully completed, and the results forwarded by letter to NSMRL for analysis.

In the interim, NUSC/NLON had modified two of the three headsets so as to reduce the maximum SPLs to which the sonarman would be exposed. The manner in which this was accomplished will be the subject of a Technical Report from NUSC/NLON, Code EB2.

RESULTS

Severity of Exposure.

The definition of exposure was of degree of severity of echo-ranging either "light to moderate" (either one or two destroyer contacts at a range from USS GATO in excess of 10 kyds) or "heavy" (usually two destroyer contacts within 5 kyds). Under these two conditions, Table I gives the SPLs measured by placing the unmodified headset on the flat-plate coupler. It is seen that under 5 of 6 conditions the tentative DRC of 95 dB is exceeded.

The reduced levels existing in the modified headsets can be inferred from Table II. Table III extracts, from the graphs originally attached to Table II, only that information in the relevant frequency region (3-4 kHz).

Table I. Sound Pressure Levels* on Three Types of Sonar Sets While Echo-Ranging

	Light to Moderate Echo-Ranging			Heavy Echo-Ranging		
2400-4800 Hz	BQS-6P	BQS-6A	BQR-7A	BQS-6P	BQS-6A	BQR-7A
	104 dB	106 dB	90 dB	108 dB	114 dB	118 dB

*SPLs taken with General Radio 1558-A octave-band analyzer and USS GATO Standard headset on flat-plate coupler. Headset column set at average level used by all sonarmen with open filters.

Table II. (From Enclosure (2) to Reference (9))

HEADSET DATA SUMMARY

1. The standard headset used by GATO is Roanwell MX2805/AIC. NUSC/NL Code EB2 provided GATO with two headsets modified by the addition of internal clipping circuitry.
2. Headset No. 1 is a modified Telephonics TC-136P. Headset No. 2 is a modified Superex ST-PRO.
3. These headsets were used with the BQS-6 peak limiter set to clip at 40 volts peak to peak.
4. The accompanying graphs for headsets 1 and 2 illustrate the frequency response of these headsets for clipped and unclipped inputs. The bottom traces are of unclipped frequency response with .175 volts peak to peak input. The upper traces are of the clipped frequency response with 3 volt RMS input.
5. Both modified headsets appreciably reduced the discomfort to the sonar operators caused by nearby echo-ranging but did not affect operator ability to analyze contacts. Headset No. 2 appeared to be slightly more effective in this respect but was less comfortable and admitted more background noise from the sonar control center.

Table III. Output in SPL on a Flat-Plate Coupler of Modified Headphones Nos. 1 and 2 at 0.175 and 3.0 Volts at Two Frequency Ranges Measured by HM1 (SS) (DV) A. M. Classen

Volts in	Phone No. 1 (Left) 3.5 kHz	4 kHz	Phone No. 1 (Right) 3.0 kHz	4 kHz
0.175	76.0	-	74.0	-
3.0	90.0	91.0	89.0	90.0
	Phone No. 2 (Left)		Phone No. 2 (Right) 3.5 kHz	
0.175	68.0	-	75.0	-
3.0	84.5	-	90.0	-

Audiometric Changes

(1) Cruise of 19-31 January 1971

Table IV gives the differences between the baseline audiogram (established during the first day prior to any echo-ranging) compared with the last audiogram taken aboard, on the last day at sea. In the audiometric workspace (CPO Quarters), the levels of noise in all audiometric octaves were less than allowable according to reference (1).

It is seen that 11 of 22 ears seemed to show losses of 10 dB or more, as compared with 4 ears which showed improvements limited to a maximum of 10 dB. Of these 11 ears, 3 showed losses of 15-20 dB. It should be noted that an unspecified time, of at least 24 hours, had elapsed between the time of the last noise exposure and the final audiogram.

Since by the time the final audiogram was collected the men had had a day or more of recovery, Table V was prepared comparing the baseline audiogram to that collected shortly after the last watch on an audiogram was in fact collected. This last documented watch occurred after from 1-5 days of exposure for the individual sonarman, so that averages cannot be computed, but Table V shows 17 of the 22 ears had a loss of more than 10 dB at 4 and/or 6 kHz, as compared with no ears showing any improvement at all, and of these 17 ears, 12 had a loss of 15 dB or more.

Table V is more to the point than Table IV, since one may then apply to the data Ward's criteria for damage risk in terms of temporary hearing losses 30 minutes following noise exposure (reference 10), of a shift of 10 dB at 3^{+} kHz as being marginally safe. From Table V it can be seen that about half the ears yielded threshold shift after 30 minutes of 15 dB, and thus exceed Ward's DRC.

(2) Cruise of 23-31 March 1971

Table VI gives the differences for each baseline audiogram compared with that just following the last involving echo-ranging. It is seen that of the 6 men who used the unmodified headphones exclusively, and were subjected to levels as in Table II, a mean loss of 10 dB occurred at 4 kHz; and of the 12 ears 6 exceeded Ward's 10 dB criterion of damage. This was the same percentage as was found on the previous cruise.

However, for the 6 men who used the modified headsets exclusively, the mean loss was only 2 dB, and only one ear exceeded Ward's DRC.

DISCUSSION

This report can only conclude that for a few day's intermittent exposure to surface ship echo-ranging, the earphone treatment here rendered the SPLs innocuous, whereas without such treatment a re-test showed that about half of all ears showed temporary losses which exceed conservative damage risk criteria.

On the other hand, one cannot reason that the problem is entirely solved. Heavier (i.e., both louder and more

Table IV. Difference Between Baseline Audiogram and that Taken on Last Day at Sea (Cruise of 19-31 January 1971)

Sonarmen		Frequency in kHz	
		4	6
STE	R	0	0
	L	0	-10
LYN	R	10	0
	L	10	0
GLE	R	10	0
	L	0	10
JUD	R	0	20
	L	0	10
SCH	R	0	-10
	L	5	0
EDM	R	0	0
	L	0	0
KER	R	10	0
	L	0	0
SIP	R	-10	0
	L	0	15
MAI	R	-5	0
	L	-10	0
SHO	R	10	20
	L	0	10
SCR	R	0	-5
	L	10	0

Table V. Differences Between Baseline Audiograms and that Following the Last Watch for Which an Audiogram was Available (Cruise of 19-31 January 1971)

Sonarmen		Frequency in kHz	
		4	6
STE	R	10	20
	L	20	0
LYN	R	20	10
	L	0	0
GLE	R	20	0
	L	0	10
JUD	R	0	20
	L	0	10
SCH	R	0	0
	L	15	10
EDM	R	10	0
	L	0	10
KER	R	20	10
	L	20	10
SIP	R	20	0
	L	10	35
MAI	R	0	0
	L	0	0
SHO	R	20	20
	L	10	0
SCR	R	0	15
	L	0	0

Table VI. Differences Between Baseline Audiogram and That Following Last Watch With Echo-Ranging (Cruise of 23-31 March 1971)

Sonarmen/ Headset			Frequency in kHz 3	4	6
UNMODIFIED:					
MAI	R		10	0	5
	L		0	15	5
JUD	R		0	15	0
	L		5	20	5
LYN	R		5	15	-5
	L		10	20	15
STC	R		0	5	0
	L		5	15	5
KER	R		0	5	-5
	L		0	5	5
GOR	R		0	0	10
	L		15	10	5
		MEAN:	2.5	10.4	4.0
MODIFIED No. 1:					
EDM	R		5	-5	-5
	L		0	-5	10
SCH	R		0	5	-5
	L		-5	-5	15
SCR	R		0	0	-10
	L		-10	5	5
MODIFIED NO. 2:					
SHO	R		0	5	-10
	L		0	10	-10
SIP	R		0	15	-5
	L		-5	10	5
STE	R		-5	-10	-5
	L		-5	-10	-5
		MEAN:	-2.0	2.0	-1.7

frequent) echo-ranging than was the case here is now being encountered elsewhere, and on the basis of these data, one may not conclude that the levels of clipping here will render harmless all such exposures. Even on the cruise of 23-31 March, with phones treated, the sonar technicians reported discomfort from time to time, and it may be that the treatment is on the verge of conservatism only for the noise conditions actually met here. Furthermore, it is still an open question whether a limiter set to clip at too low a level may not lead to a loss of information in an open-filter search.

It seems clear that a peak-limiter circuit is not only necessary to avoid permanent damage to sonar technicans in this situation, but also the manner of limiting, and the cutoff SPL should be studied both with respect to hearing damage and also its effects on the transfer and processing of information from the sea.

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Hearing Conservation Program on Sonar Technicians; request for support of

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13. ABSTRACT

Audiograms collected underway on sonar technicians on USS GATO (SSN 615) during exposure to echo-ranging 19 - 31 January 1971 showed that SPLs in the sonar headsets may be hazardous to hearing. Two of three headsets were modified by NUSC/NLON so as to limit the peak SPLs delivered to the ear. On a cruise 21 - 31 March 1971, during which light to moderately heavy echo-ranging was encountered, 6 men using an unmodified headset, were exposed to SPLs up to 118 dB. In half the 12 ears a temporary hearing loss was found which exceeded a widely-disseminated damage-risk criterion. However, of 6 men who used modified headsets, no average loss whatever was found, and only 1 ear slightly exceeded the criterion. Whether the modification introduced on this occasion was an optimal compromise between protecting the ears vs obtaining all possible information from the sea, is still an open question. Further studies are in progress.

14. KEY WORDS	LINK A		LINK B		LINK C	
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